



EPICS @ GSI and FAIR

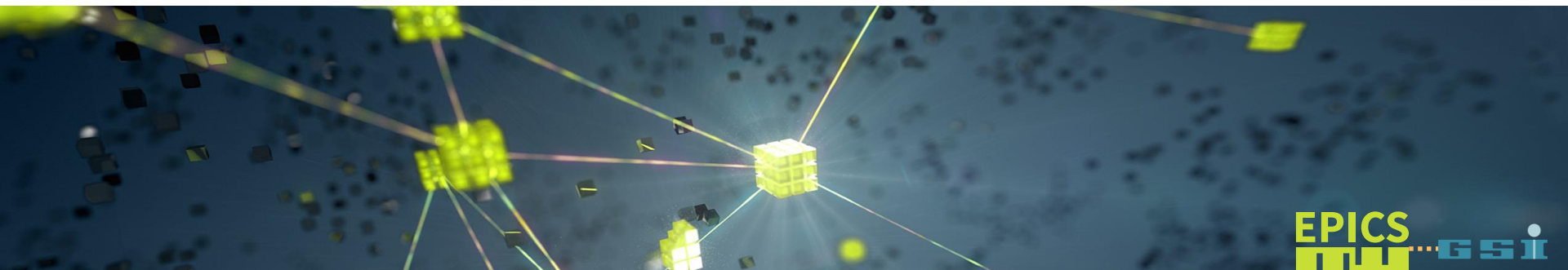
Experiment Control System Workshop, April 2023

Peter Zumbruch, GSI/EEL-EKS
2023-April-25

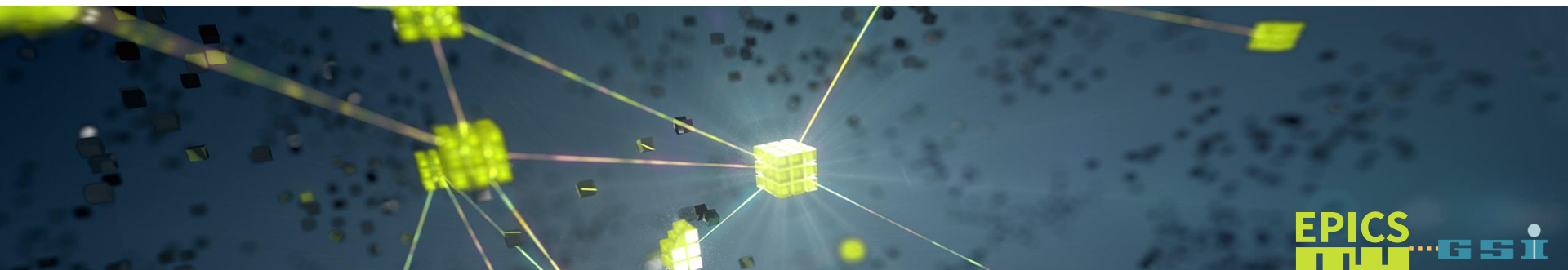
Overview

- Introduction to EPICS
- Using EPICS at
 - HADES
 - R³B
 - PANDA
 - CBM
 - ...

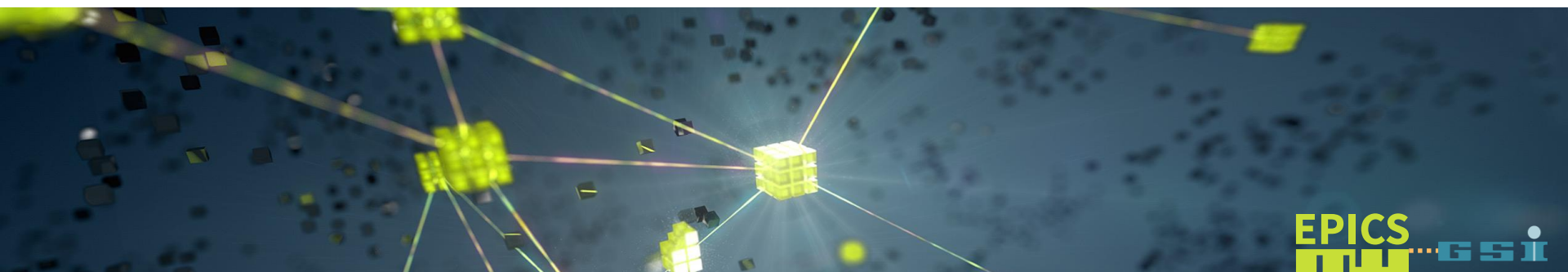
(for sure this list is probably incomplete)



INTRODUCTION TO EPICS



WHAT IS EPICS?



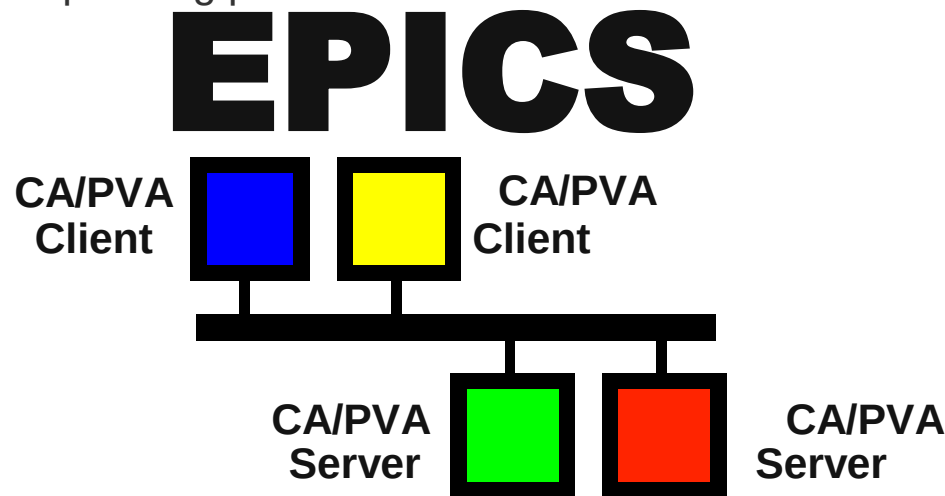
What is EPICS?

(from <https://epics-controls.org/about-epics>)

- EPICS:
 - „THE“ „*E*xperimental *P*hysics and *I*ndustrial *C*ontrol *S*ystem“
 - eco-system or a set of *software tools* and *applications*,
 - which provide a *software infrastructure* for use in building *distributed control systems* ... to operate devices such as Particle Accelerators, *Large Experiments* and major Telescopes. EPICS uses *Client/Server* and *Publish/Subscribe* techniques to communicate between the various computers.
 - Most servers (called *Input/Output Controllers* or *IOCs*)
 - perform *real-world I/O* and *local control tasks*,
 - and *publish* this information to clients using robust, EPICS specific network protocols *Channel Access* and *pvAccess*.
 - These protocols are designed for
 - *high bandwidth*,
 - *soft real-time networking applications* that EPICS is used for,
 - and is one *reason* why it can be used to build a control system *comprising hundreds* of computers.

What is EPICS? (let's see the old logo...)

- A Collaboration
- A Control System Architecture
 - Network-based “client/server” model (hence the old EPICS logo), incorporating publisher/subscribe methods



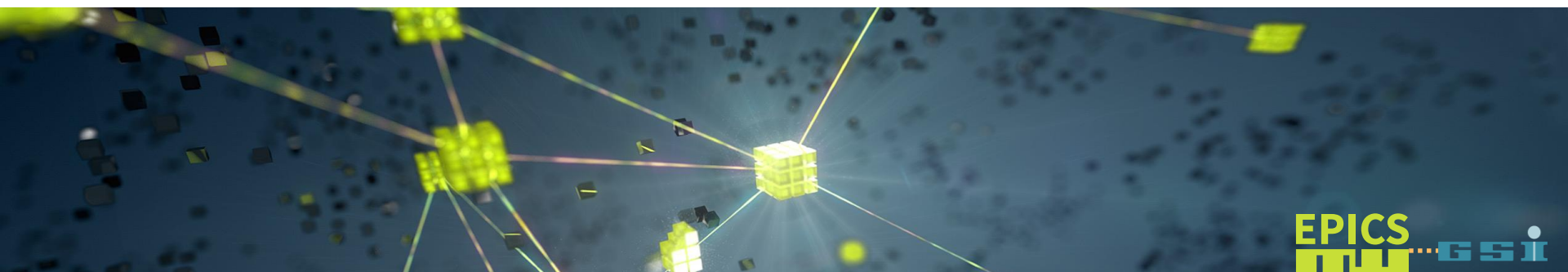
For EPICS, *client* and *server* speak of their Channel Access role
i.e. Channel Access Client & Channel Access Server
also PVAccess Client & PVAccess Server

**configuration
before
compilation!**

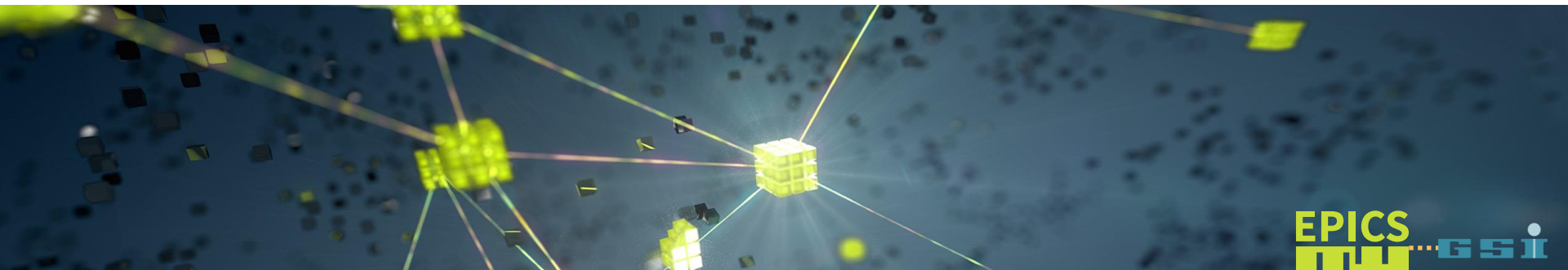
EPICS in short

- Core object: Process Variable
 - uniquely named object (e.g.: *HAD:MDC:LV:ch0:vmom*) containing, e.g. Temperature value
 - + many attributes, EGU, linear conversion, INPut or OUTput, etc.
- An IOC (Input Output Controller) is (nowadays one amidst others) a server process on a network node hosting/configuring datastructures called records, which each represents the PV and its functionality and datatype, e.g. ao, ai, bi, bo, mbbi, mbbo, calc, seq, wave
- Records can connect via their inputs/outputs
 - either to other records, building control loops/chains
 - also across the network to other IOCs
 - devices via more or less generic *device supports*, (e.g. *asyn*, *streamDevice*, *areaDetector*)
- *Together the records and their IOCs build a distributed (soft) real-time database of process variables*
- *clients and servers connect to each other using the Channel Access or the newer PV Access protocol, often via publisher/subscriber methods*
- *Thus Clients can be many applications capable of the above mentioned protocols,*
 - *CLI, GUI, Archiver, many language APIs, e.g. python pyepics, ...*

DCS DETECTOR CONTROL SYSTEM

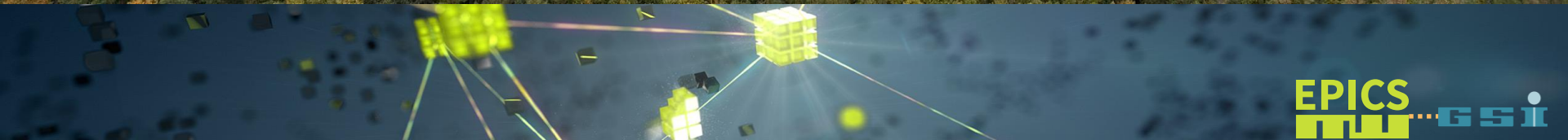


HADES

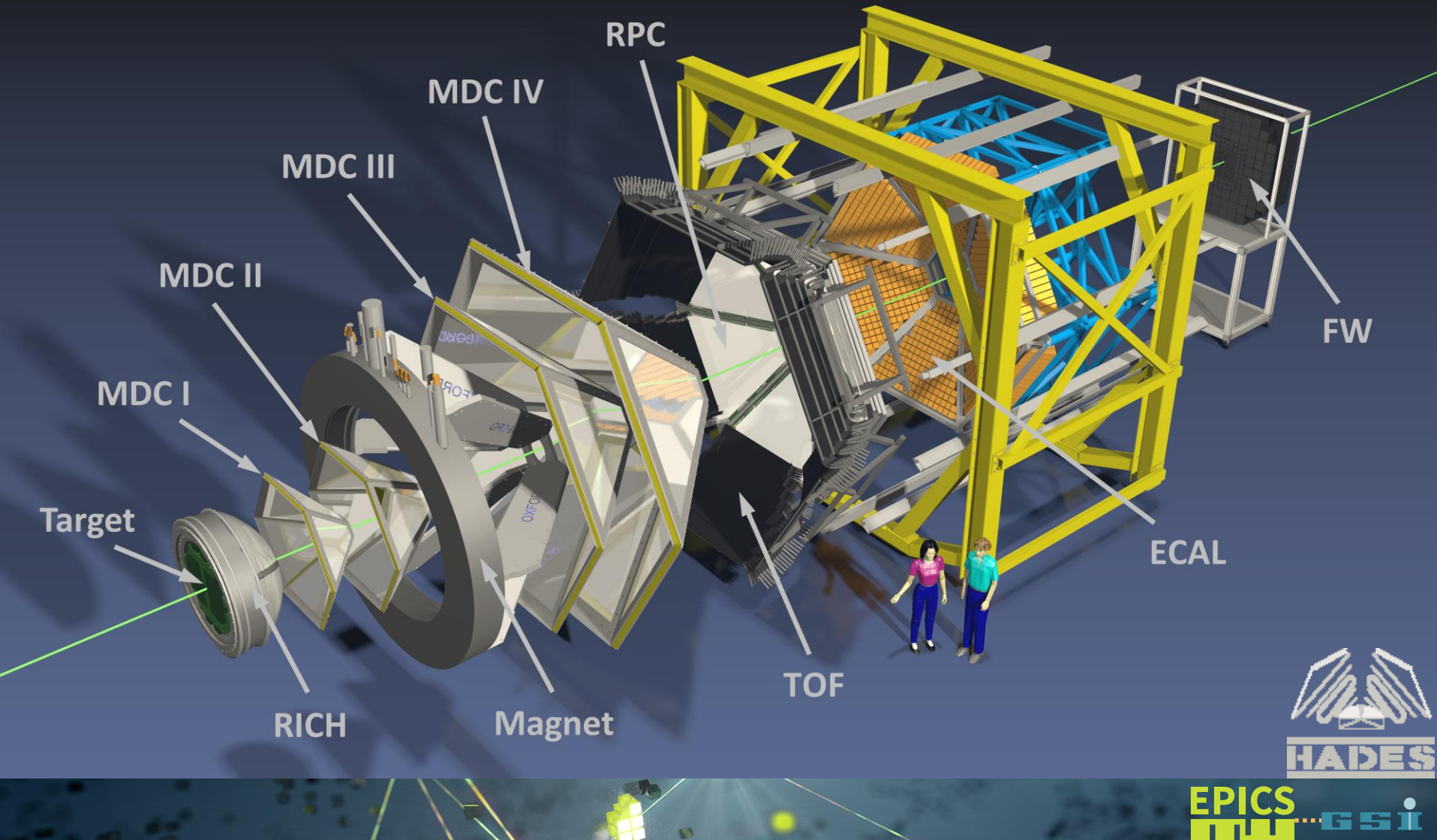




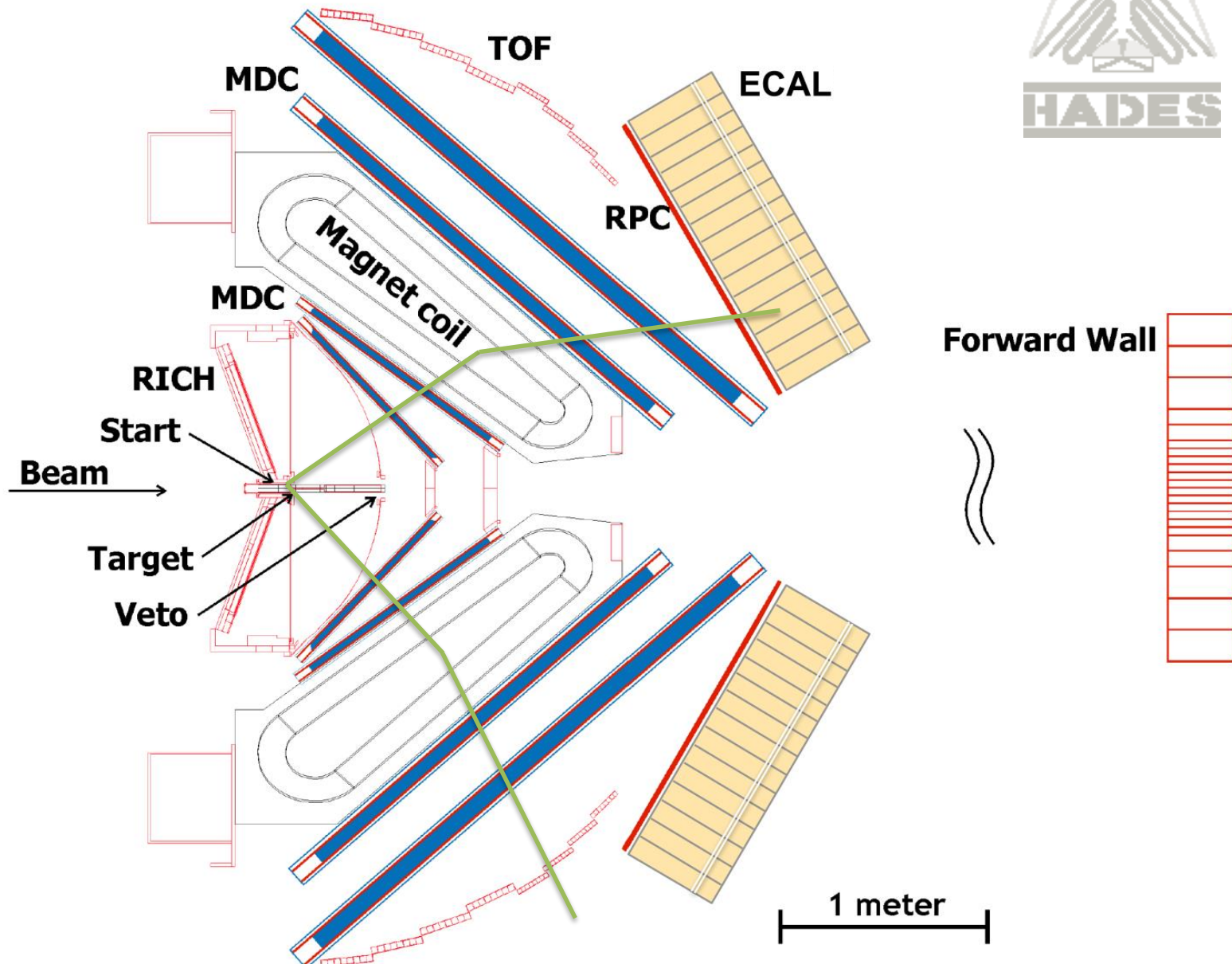
D.Fehrenz GSI/FAIR



HADES – High Acceptance DiElectron Spectrometer (setup Ag+Ag)



HADES (2) – Vertical cut

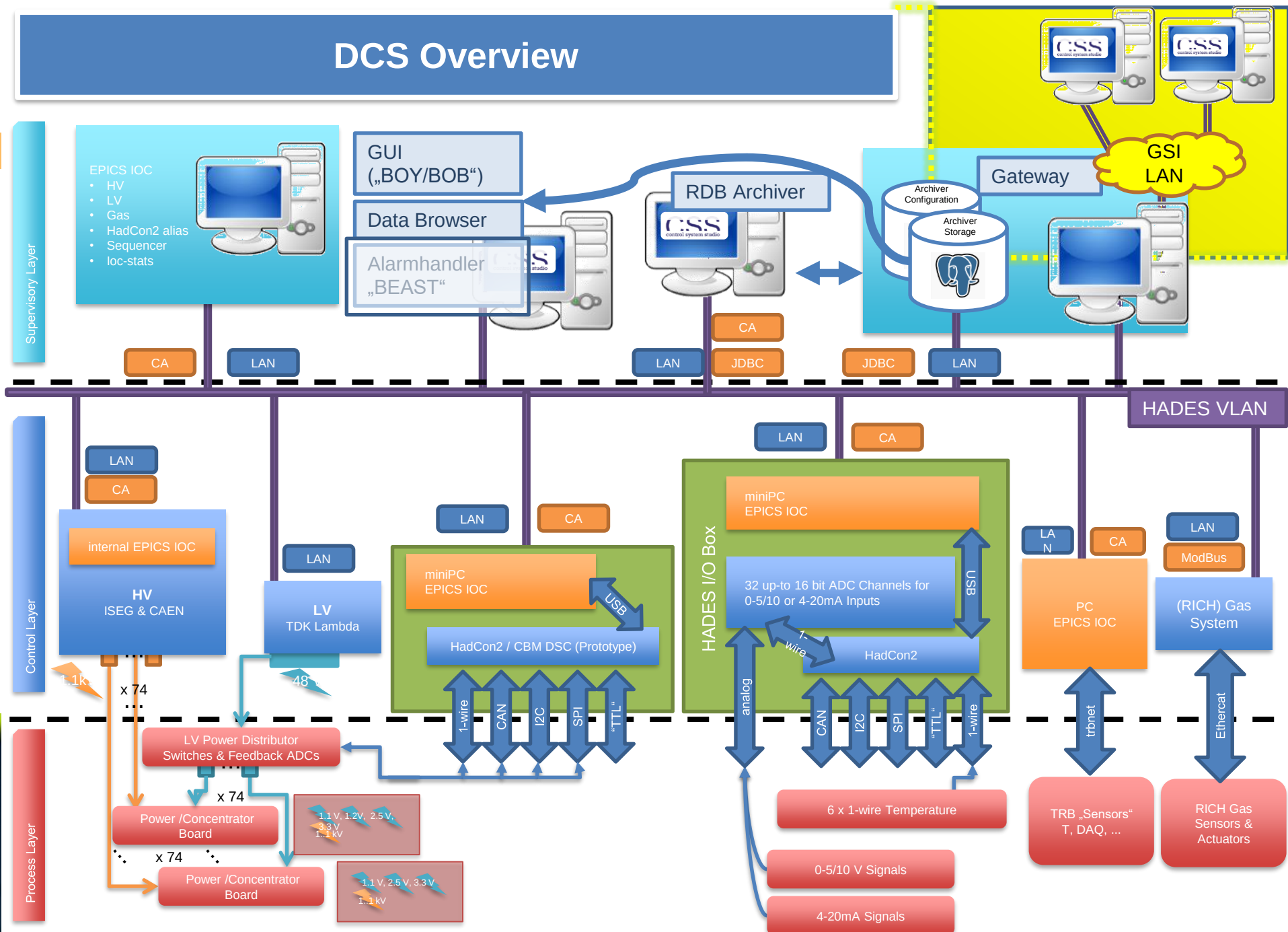


Overview and Status (2022-...)

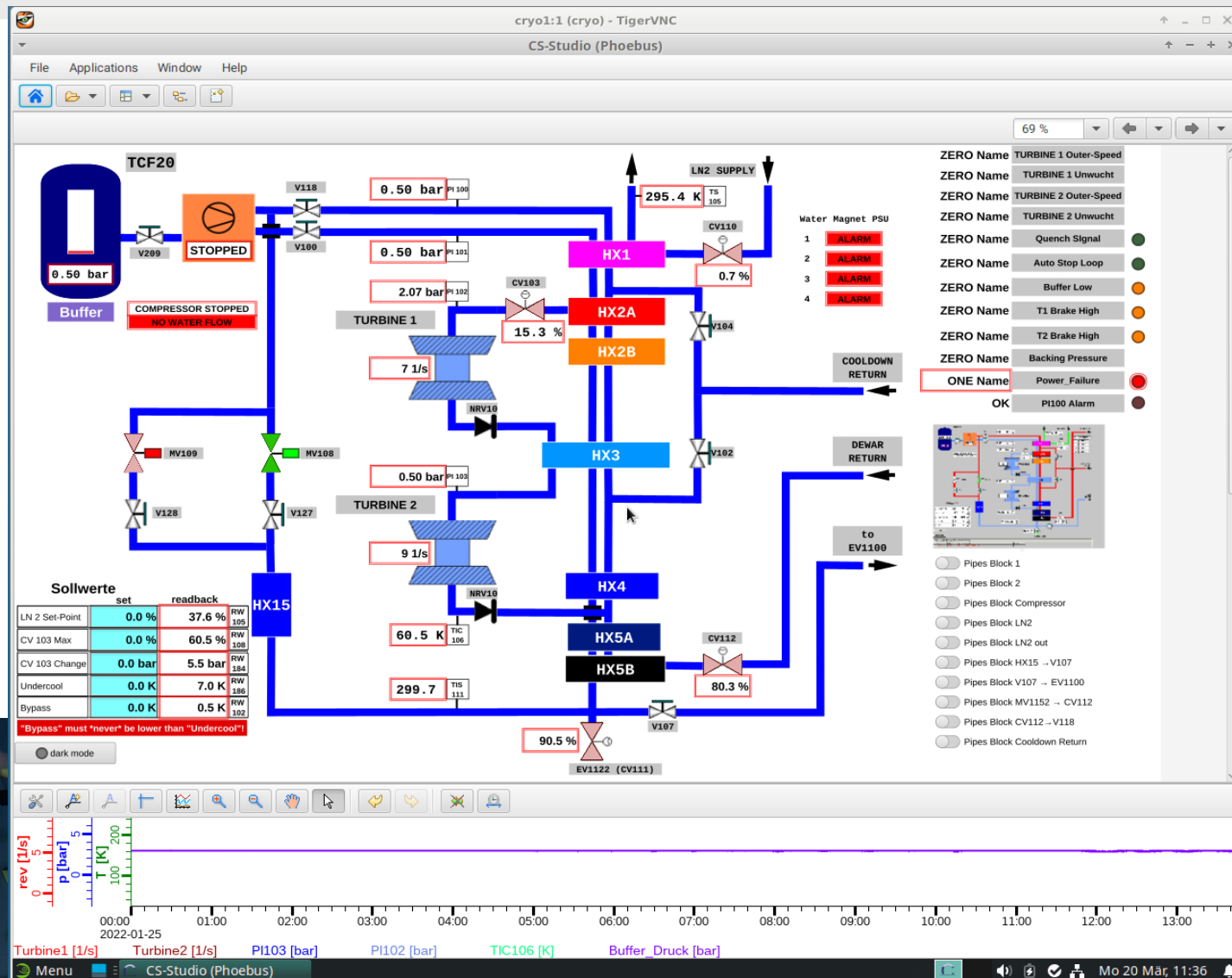
• HADES control system

- EPICS system
- ~ 300,000 Process Variables
 - Temperature, HV, LV, pressures, scales, switches, gas systems, magnet, cryo status, vacuum, beamline
- ~ 34 compute nodes “IOCs” (Input Output Controller)
 - 4 central (linux-x86_64)
 - „Main IOC“, FSM Sequencer, HV and LV control, ~80k PV
 - 2 larger: ~13k and ~90k PV
 - MCS (old and new) ~10k PV
 - embedded ISEG IOC ~10kPV
 - 9 embedded CAEN IOC (HV) in total ~90k PV
 - 19++ smaller (linux-arm, etrax, linux-x86_64)
 - HadCon1 (etrax FX)
 - HadCon2 + dreamPlug/Raspberry PI
 - Raspberry PI
- Visualization / GUI client
 - phoebus (all lxhaddcsXY and lxhadeb07)
 - Older CSS 4.4
 - Medm (only lxhaddcs05/06)
- Archiving
 - archiver for ~13,000 Process Variables at 0.1 to 10 Hz
 - CS-Studio based headless RDB Archiver
 - connecting to local containerized PostgreSQL database
- Involved institutes
 - GSI, Gießen, Krakow

DCS Overview



Operator's VIEW (1) cryo



tMCS (technical view)

ADAM 4017, 4017P, 4021, 4024, 4050, 4052

Module 11

open

moduleName

4017P

firmware

A2.02

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

individual per cha

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
11 0	2.5 mA	2.494 mA x 1.000	+0.000 mA		4-20 mA	TP2210
11 1	2.5 mA	2.493 mA x 1.000	+0.000 mA		4-20 mA	TP2208
11 2	2.5 mA	2.495 mA x 1.000	+0.000 mA		4-20 mA	TP2206
11 3	2.5 mA	2.493 mA x 1.000	+0.000 mA		4-20 mA	TP2204
11 4	2.5 mA	2.496 mA x 1.000	+0.000 mA		4-20 mA	TP2202
11 5	2.5 mA	2.496 mA x 1.000	+0.000 mA		4-20 mA	TP2216
11 6	2.5 mA	2.492 mA x 1.000	+0.000 mA		4-20 mA	TP2214
11 7	2.5 mA	2.494 mA x 1.000	+0.000 mA		4-20 mA	TP2212

offset calibration (7s)

gain calibration

Module 12

open

moduleName

4017P

firmware

A2.02

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

individual per cha

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
12 0	2.9 mA	2.882 mA x 1.000	+0.000 mA		4-20 mA	TP2200
12 1	2.9 mA	2.884 mA x 1.000	+0.000 mA		4-20 mA	TP2224
12 2	2.9 mA	2.883 mA x 1.000	+0.000 mA		4-20 mA	TP2220
12 3	2.9 mA	2.877 mA x 1.000	+0.000 mA		4-20 mA	TP2222
12 4	2.9 mA	2.879 mA x 1.000	+0.000 mA		4-20 mA	TP2228
12 5	2.9 mA	2.878 mA x 1.000	+0.000 mA		4-20 mA	TP2226
12 6	2.9 mA	2.873 mA x 1.000	+0.000 mA		4-20 mA	TP2230
12 7	2.9 mA	2.871 mA x 1.000	+0.000 mA		4-20 mA	TP2226

offset calibration (7s)

gain calibration

Module 13

open

moduleName

4017P

firmware

A2.02

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

individual per cha

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
13 0	19.6 mA	19.649 mA x 1.000	+0.000 mA		4-20 mA	TP1262
13 1	19.4 mA	19.356 mA x 1.000	+0.000 mA		4-20 mA	TP1260
13 2	19.5 mA	19.541 mA x 1.000	+0.000 mA		4-20 mA	TP2229
13 3	19.6 mA	19.653 mA x 1.000	+0.000 mA		4-20 mA	NC-13.3
13 4	19.7 mA	19.653 mA x 1.000	+0.000 mA		4-20 mA	NC-13.4
13 5	19.8 mA	19.830 mA x 1.000	+0.000 mA		4-20 mA	NC-13.5
13 6	19.6 mA	19.559 mA x 1.000	+0.000 mA		4-20 mA	NC-13.6
13 7	19.7 mA	19.664 mA x 1.000	+0.000 mA		4-20 mA	NC-13.7

offset calibration (7s)

gain calibration

Module 61

open

moduleName

4017

firmware

D1.7

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

V

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
61 0	0.3 V	0.333 V x 1.000	+0.000 V		+10 V	EV1128R
61 1	0.5 V	0.492 V x 1.000	+0.000 V		+10 V	FI140C(a)
61 2	0.0 V	0.003 V x 1.000	+0.000 V		+10 V	Crowbar(a)
61 3	0.0 V	0.002 V x 1.000	+0.000 V		+10 V	Spare-61.3
61 4	0.3 V	0.323 V x 1.000	+0.000 V		+10 V	NC-61.4
61 5	0.5 V	0.481 V x 1.000	+0.000 V		+10 V	HR310C(a)
61 6	0.5 V	0.482 V x 1.000	+0.000 V		+10 V	HR3102(a)
61 7	0.4 V	0.380 V x 1.000	+0.000 V		+10 V	NC-61.7

offset calibration

gain calibration

Module 62

open

moduleName

4052

firmware

D1.1

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
62 0	0x10
62 1	0x10
62 2	0x10
62 3	0x10
62 4	0x10
62 5	0x10
62 6	0x10
62 7	0x10

data input byte

0b100000

Module 63

open

moduleName

4050

firmware

D1.6

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
63 0	0x7F
63 1	0x7F
63 2	0x7F
63 3	0x7F
63 4	0x7F
63 5	0x7F
63 6	0x7F
63 7	0x7F

data output feedback byte

0b111111

Module 71

open

moduleName

4017

firmware

D1.7

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

V

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
71 0	0.5 V	0.485 V x 1.000	+0.000 V		+10 V	LL1708
71 1	0.0 V	0.000 V x 1.000	+0.000 V		+10 V	PI1612
71 2	0.0 V	0.000 V x 1.000	+0.000 V		+10 V	PI1610
71 3	0.0 V	0.000 V x 1.000	+0.000 V		+10 V	PI1600
71 4	0.0 V	0.000 V x 1.000	+0.000 V		+10 V	PI1602
71 5	-0.0 V	-0.003 V x 1.000	+0.000 V		+10 V	NC-71.5
71 6	-0.0 V	-0.003 V x 1.000	+0.000 V		+10 V	PI1600
71 7	-0.0 V	-0.003 V x 1.000	+0.000 V		+10 V	PI1604

offset calibration

gain calibration

Module 72

open

moduleName

4017

firmware

D1.7

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

V

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
72 0	2.7 V	2.734 V x 1.000	+0.000 V		+10 V	HR3104(a)
72 1	9.3 V	9.263 V x 1.000	+0.000 V		+10 V	CC-sw(a)
72 2	9.3 V	9.269 V x 1.000	+0.000 V		+10 V	LHe_bol(a)
72 3	-0.3 V	-0.338 V x 1.000	+0.000 V		+10 V	CBDrumk(a)
72 4	7.6 V	7.639 V x 1.000	+0.000 V		+10 V	LL1700(a)
72 5	7.6 V	7.641 V x 1.000	+0.000 V		+10 V	LL1702(a)
72 6	7.6 V	7.642 V x 1.000	+0.000 V		+10 V	LL1704(a)
72 7	7.6 V	7.642 V x 1.000	+0.000 V		+10 V	LL1706(a)

offset calibration

gain calibration

Module 74

open

moduleName

4017P

firmware

A2.02

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

individual per cha

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
74 0	4.0 mA	3.980 mA x 1.000	+0.000 mA		4-20 mA	HR3104
74 1	4.0 mA	3.970 mA x 1.000	+0.000 mA		4-20 mA	HR3106
74 2	-999999	-999999	negativ overrun		4-20 mA	NC-74.2
74 3	-999999	-999999	negativ overrun		4-20 mA	NC-74.3
74 4	-999999	-999999	negativ overrun		4-20 mA	NC-74.4
74 5	-999999	-999999	negativ overrun		4-20 mA	NC-74.5
74 6	-999999	-999999	negativ overrun		4-20 mA	NC-74.6
74 7	-999999	-999999	negativ overrun		4-20 mA	NC-74.7

offset calibration (7s)

gain calibration

Module 81

open

moduleName

4017

firmware

D1.7

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

V

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
81 0	2.5 V	2.525 V x 1.000	+0.000 V		+10 V	EV1218LUX
81 1	9.3 V	9.297 V x 1.000	+0.000 V		+10 V	EV1122S
81 2	5.1 V	5.095 V x 1.000	+0.000 V		+10 V	EV1122R
81 3	0.0 V	0.001 V x 1.000	+0.000 V		+10 V	EV1122LUX
81 4	0.1 V	0.124 V x 1.000	+0.000 V		+10 V	VG3000
81 5	0.1 V	0.063 V x 1.000	+0.000 V		+10 V	MV1106R
81 6	0.0 V	0.001 V x 1.000	+0.000 V		+10 V	MV1106LUX
81 7	0.0 V	0.001 V x 1.000	+0.000 V		+10 V	MV1202LUX

offset calibration

gain calibration

Module 82

open

moduleName

4017

firmware

D1.7

Engineering units

115.2 kbps

conf.dataFormat

Engineering units

conf.baudRate

115.2 kbps

conf.integrationTime

50 ms (@60 Hz power)

conf.checksumStatus

Disabled

EGU

V

MUX

00000000

modch	value (prec-1)	raw	slope	offset	range	target
82 0	0.1 V	0.115 V x 1.000	+0.000 V		+10 V	CPWA-THAD-M
82 1	1.9 V	1.859 V x 1.000	+0.000 V		+10 V	TP2228(a)
82 2	0.1 V	0.116 V x 1.000	+0.000 V		+10 V	SPS_Q3
82 3	0.1 V	0.114 V x 1.000	+0.000 V		+10 V	EV1100S
82 4	0.1 V	0.150 V x 1.000	+0.000 V		+10 V	EV1100R
82 5	0.1 V	0.115 V x 1.000	+0.000 V		+10 V	EV1100LUX
82 6	0.1 V	0.116 V x 1.000	+0.000 V		+10 V	EV1100G(a)
82 7	0.1 V	0.116 V x 1.000	+0.000 V		+10 V	EV1218F(a)

offset calibration

gain calibration

Module 83

open

moduleName

4050

firmware

D1.6

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
83 0	0x7F
83 1	0x7F
83 2	0x7F
83 3	0x7F
83 4	0x7F
83 5	0x7F
83 6	0x7F
83 7	0x7F

data output feedback byte

0b1111100001100001

Module 84

open

moduleName

4024

firmware

A2.11

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
84 0	0x7F
84 1	0x7F
84 2	0x7F
84 3	0x7F
84 4	0x7F
84 5	0x7F
84 6	0x7F
84 7	0x7F

data output feedback byte

0b11111111

Module 85

open

moduleName

4050

firmware

D1.6

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
85 0	0x7F
85 1	0x7F
85 2	0x7F
85 3	0x7F
85 4	0x7F
85 5	0x7F
85 6	0x7F
85 7	0x7F

data output feedback byte

0b1101010

Module 86

open

moduleName

4021

firmware

D1.1

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

Disabled

EGU

V

MUX

00000000

mod bit	target
86 0	0x7F
86 1	0x7F
86 2	0x7F
86 3	0x7F
86 4	0x7F
86 5	0x7F
86 6	0x7F
86 7	0x7F

data output feedback byte

0b1111100001100001

Module 87

open

moduleName

4050

firmware

D1.6

Engineering units

115.2 kbps

conf.dataFormat

Advantec

conf.baudRate

115.2 kbps

conf.protocol

Advantec

conf.checksum

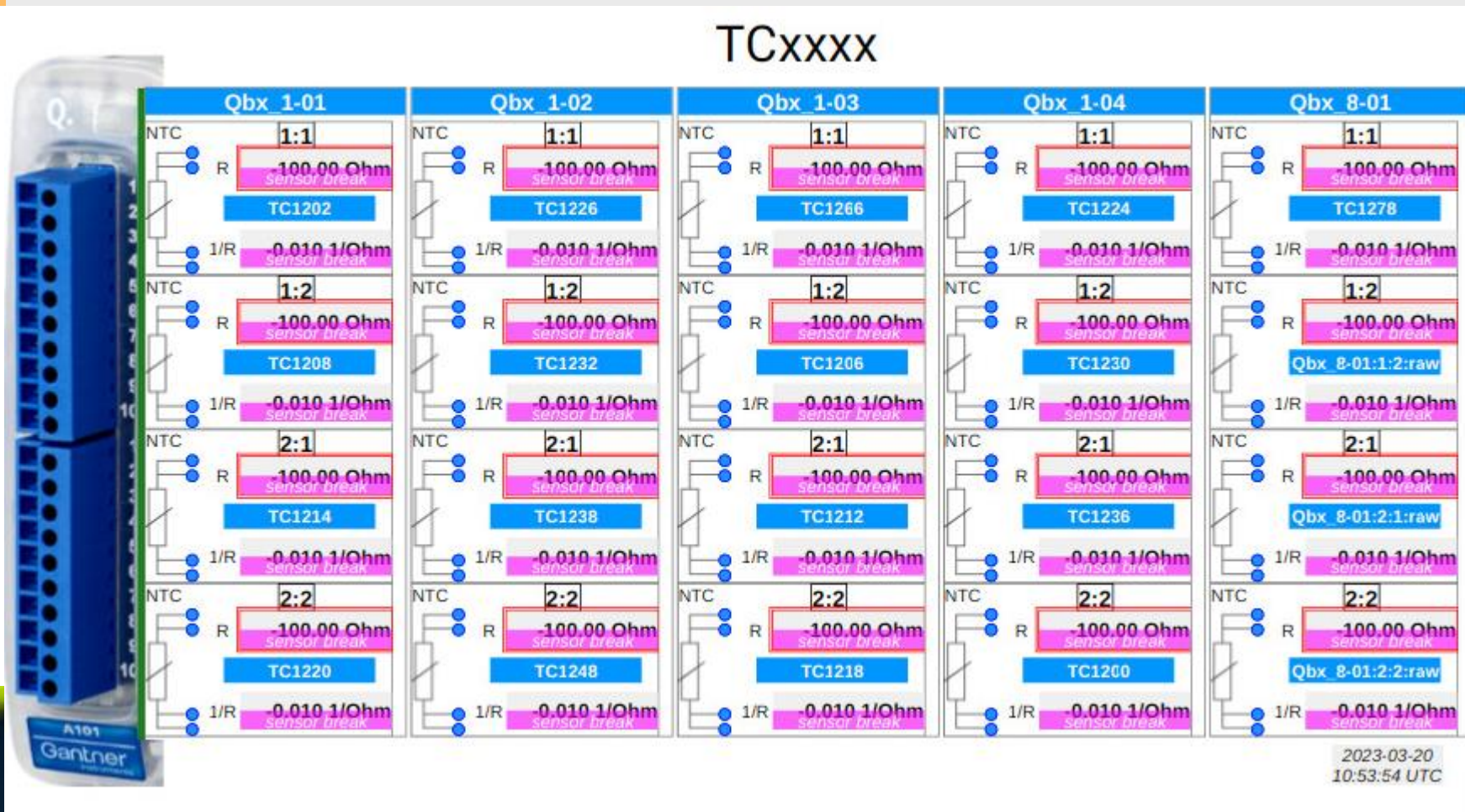
Disabled

EGU

V

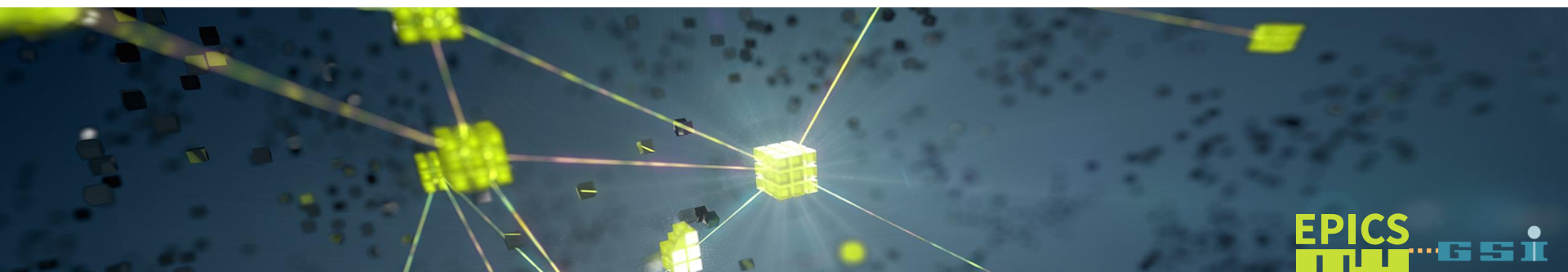
M

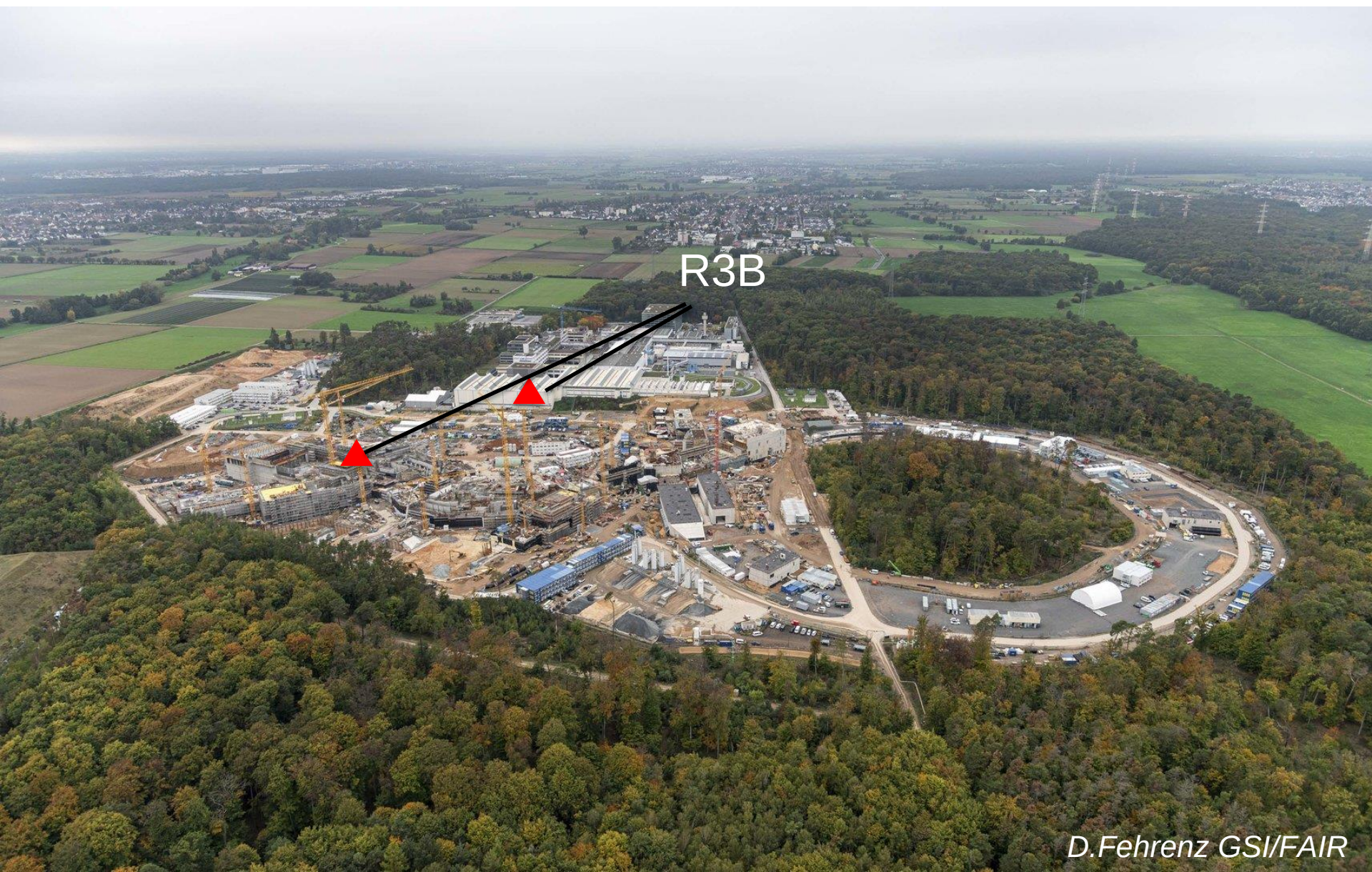
tMCS (technical view) - Gantner



R³B

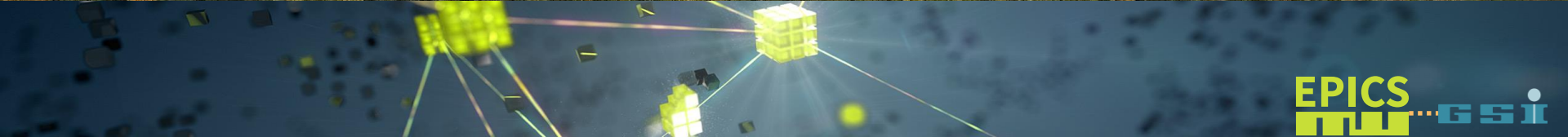
Reactions with Relativistic Radioactive Beams

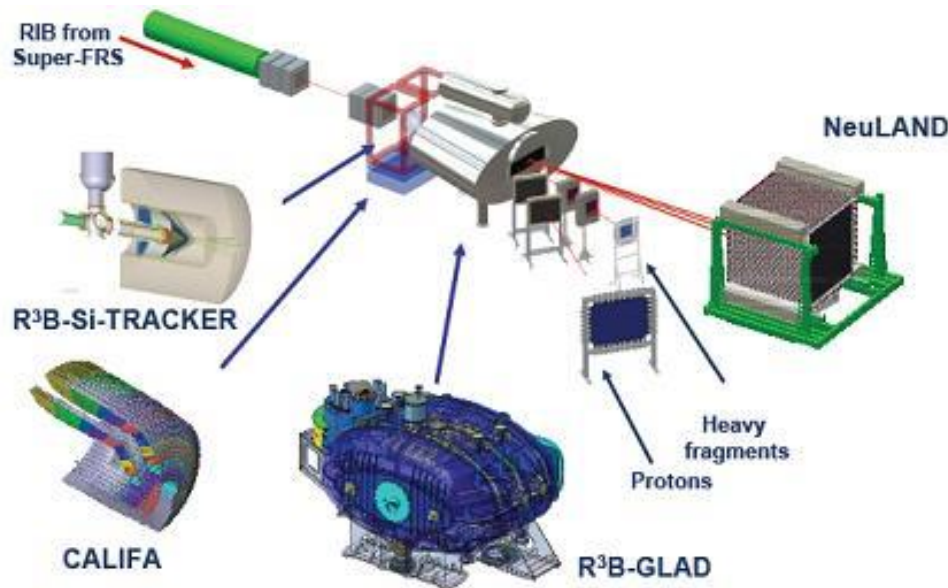




R3B

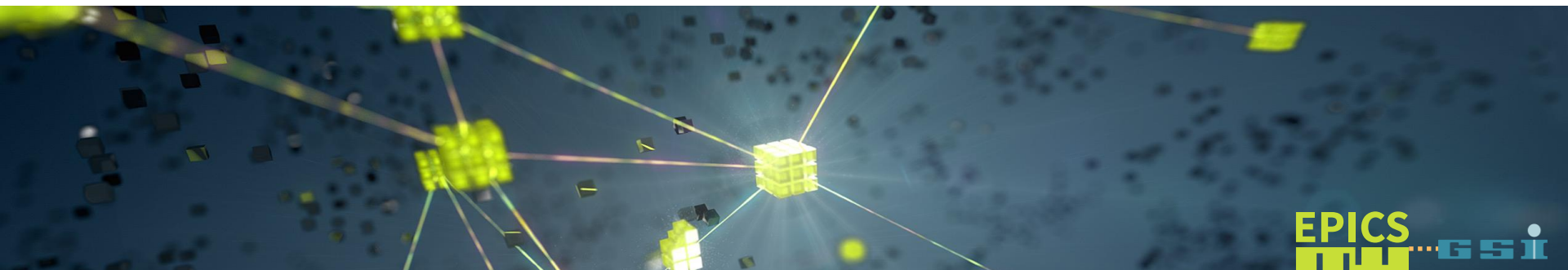
D.Fehrenz GSI/FAIR





The R3B (Reactions with Relativistic Radioactive Beams) setup at FAIR will serve the investigation of nuclear reactions with exotic nuclei far from stability. In this approach the nuclei typically have velocities of several 10th of the speed of light. Due to the expected low production rates of the most exotic nuclei that can be reached, a high efficiency is necessary in this experiment. Reaction products, that is particles like protons and neutrons, as well as gamma radiation, will be detected as exhaustive as possible by a complex detector system.

<http://www.fair-nustar.de/en/experiments/r3b-eng.html>

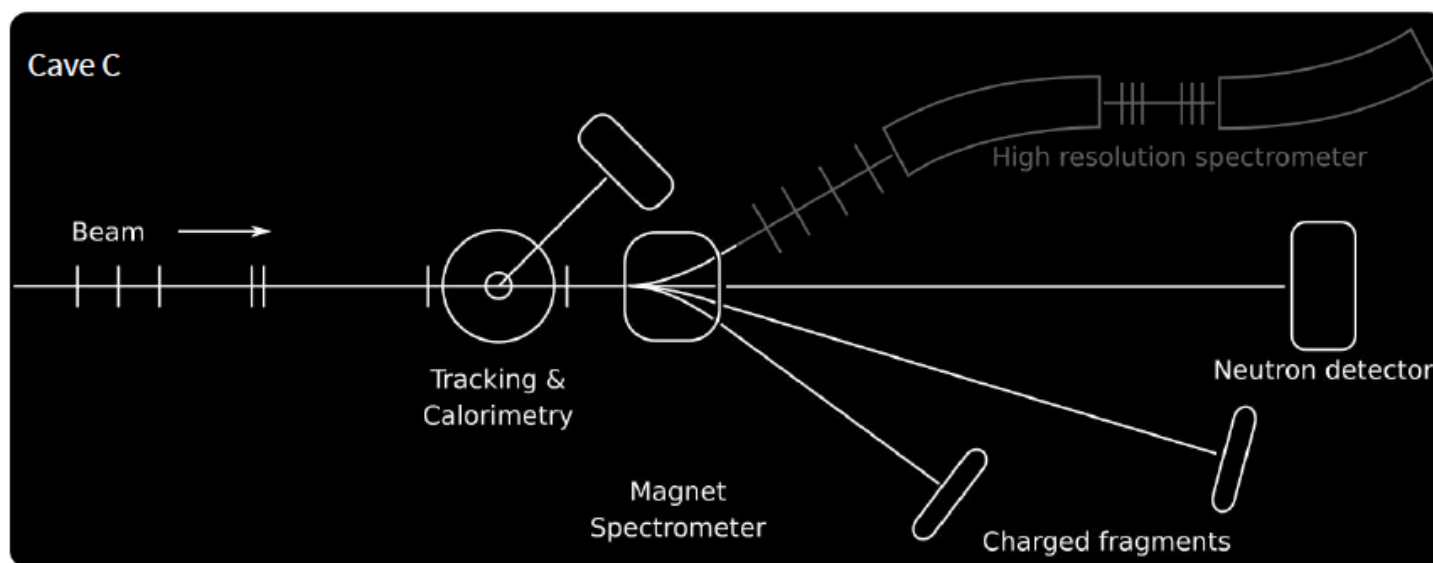


courtesy to B.Loehner, controls coordination

The R³B setup

Reactions with relativistic beams in inverse kinematics

- fixed target experiment, allows high-resolution kinematically complete measurements
- tracking of incoming beam & outgoing fragments (neutrons, light and heavy charged fragments)



The R³B setup - Under control

Scope

- Goal is to control / monitor as much as needed for remote operation, minimize access to Cave C
- Parameters under control / monitoring:
 - Detector front-end cards
 - High / Low voltage power supplies
 - Power distribution units / power strips
 - VME / NIM crates
 - Motor controllers
 - Pressure gauges
 - Gas systems
 - Temperatures
 - Scopes
 - GSI FESA Accelerator parameters
 - R³B DAQ
 - some more I forgot...
- **Today:** Bits and pieces that have solved some of our problems

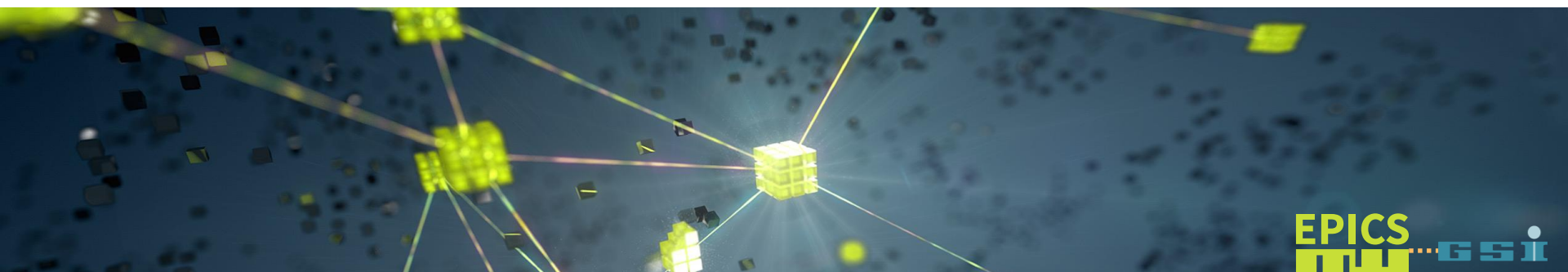
PANDA

transparencies taken from 2018-06-20

PANDA Detector Control System

Joint CBM/PANDA DCS Workshop

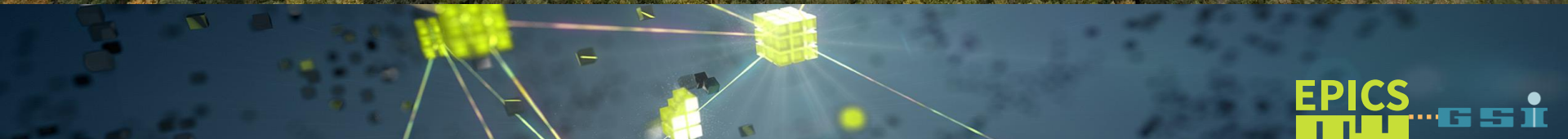
Florian Feldbauer



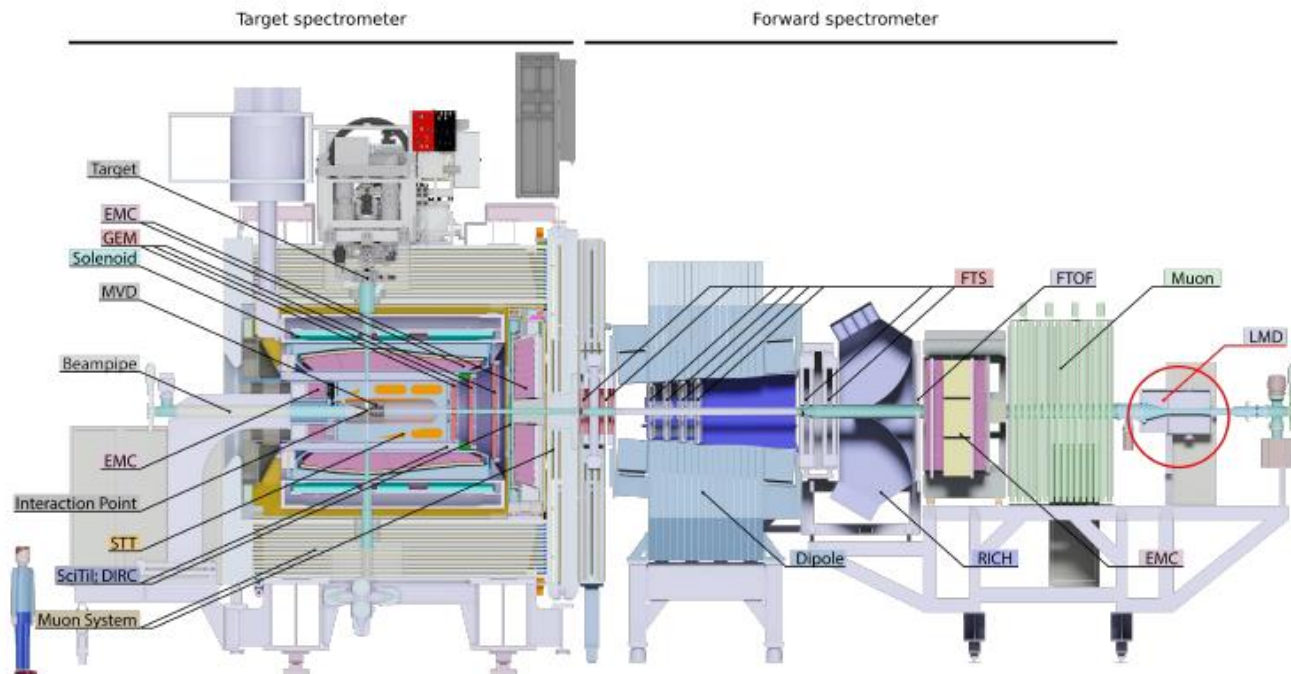


PANDA

D.Fehrenz GSI/FAIR



The PANDA Detector



PANDA physics program:

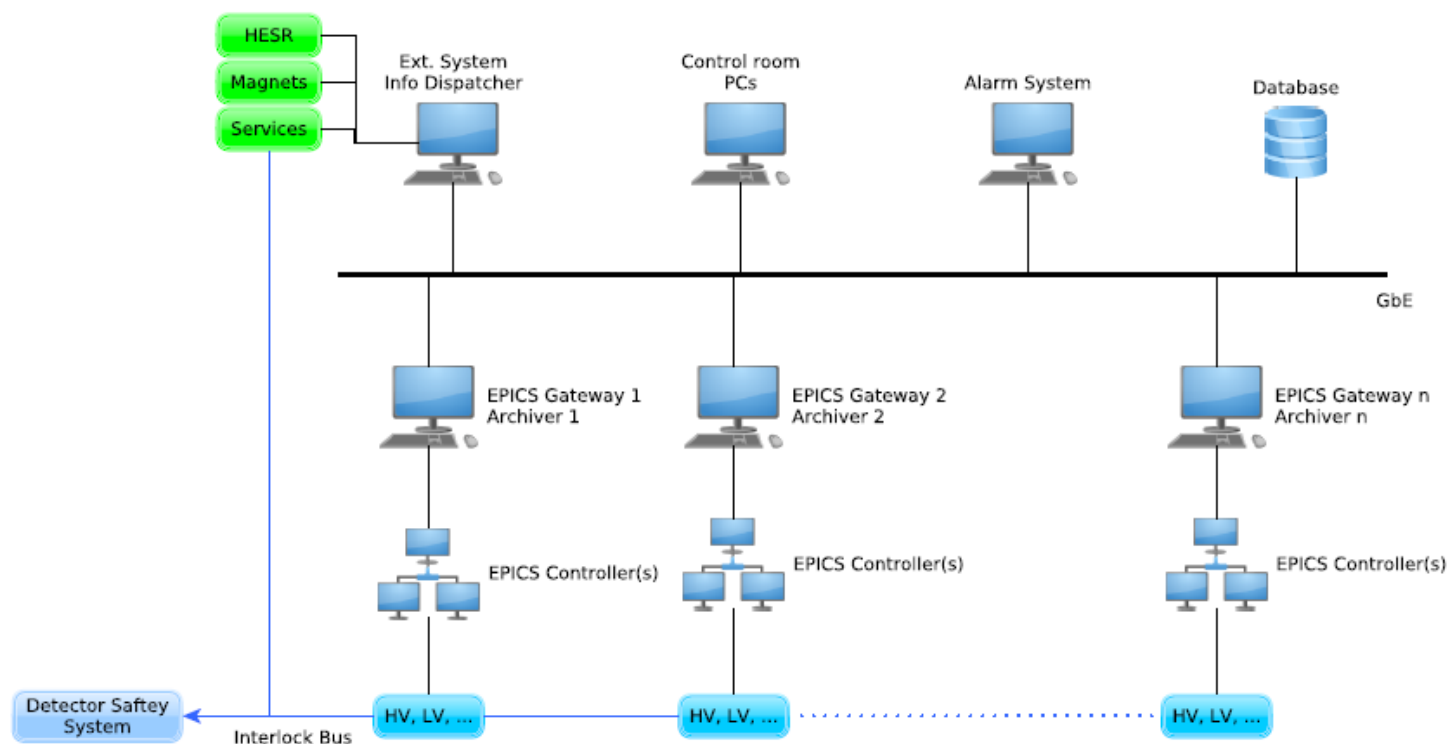
- Hadron spectroscopy
- Hadron structure
- Hadrons in medium
- Hypernuclear physics

DCS Overview

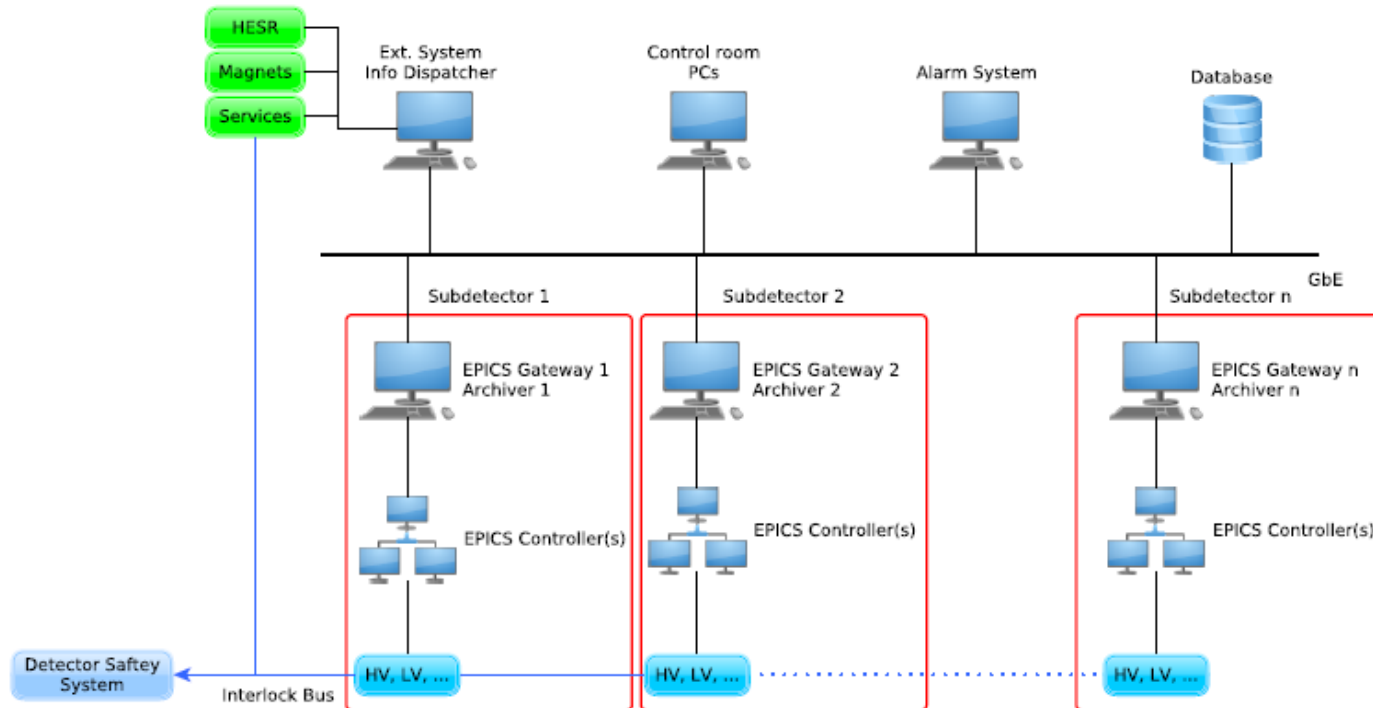
Supervisory Layer

Controls Layer

Process Layer



DCS Overview

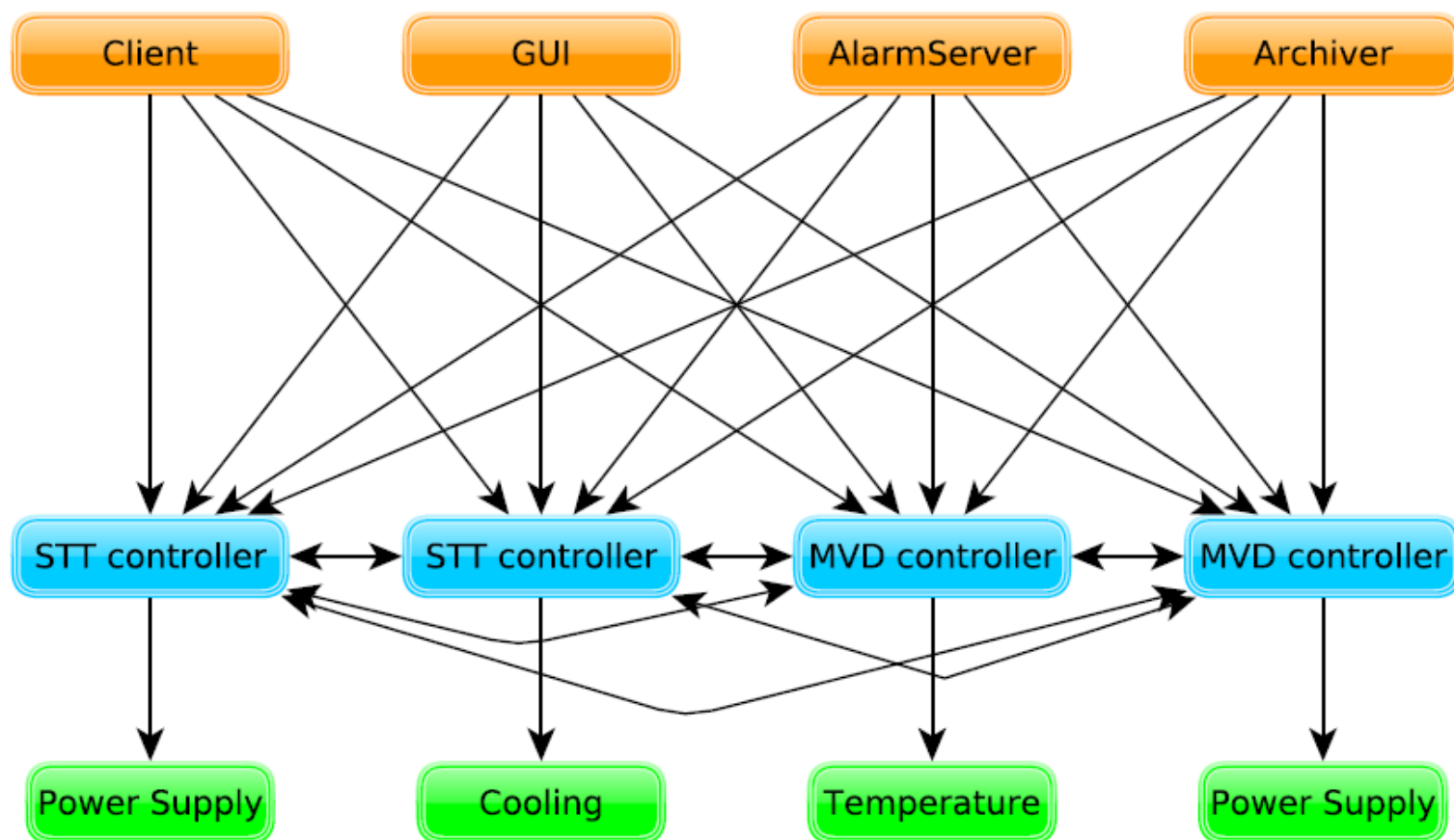


EPICS - **E**xperimental **P**hysics and **I**ndustrial **C**ontrol **S**ystem

- Decentralized architecture
- Freely scalable
- Allows "partitioning" $\Rightarrow$ each subdetector has its own DCS

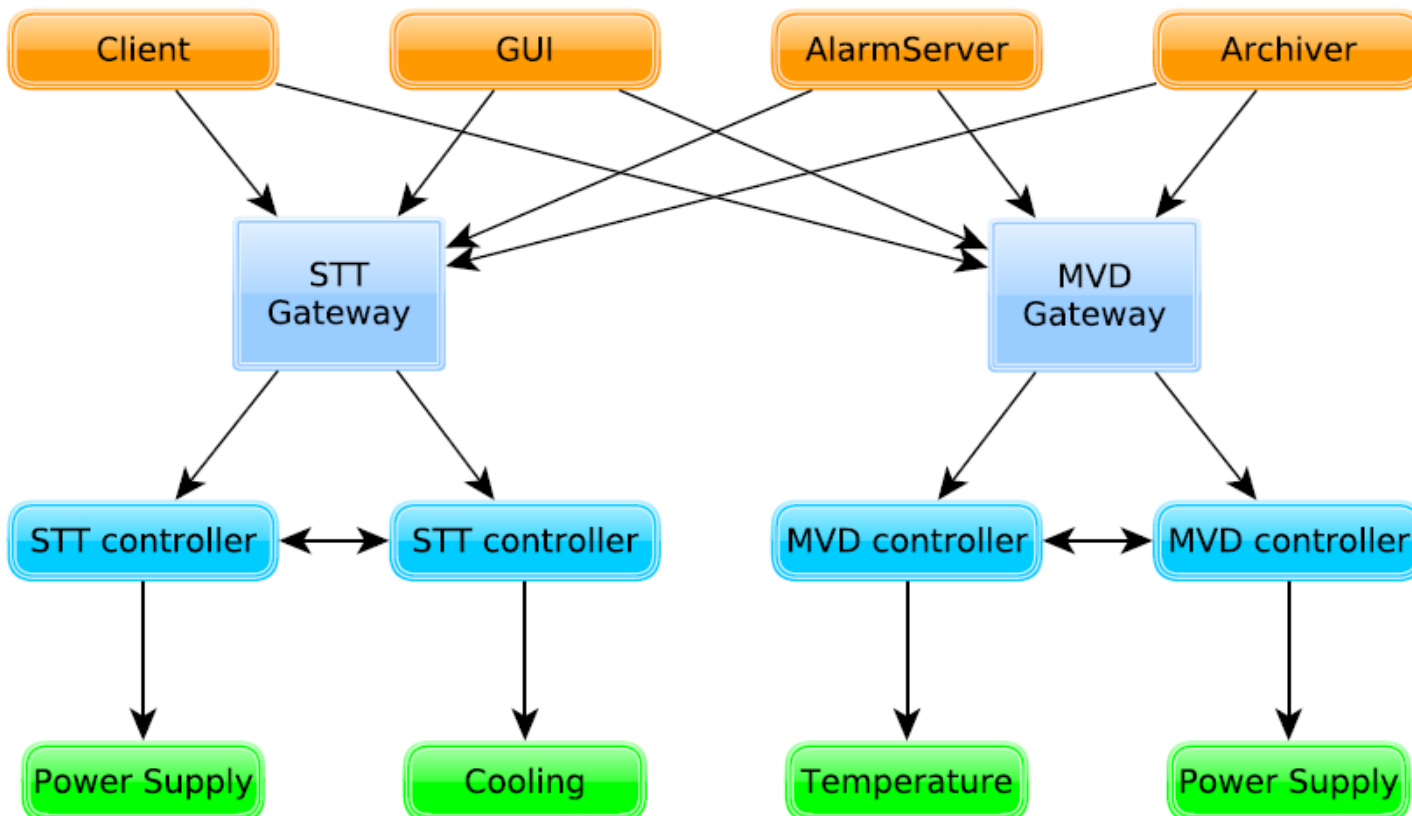
EPICS Communication Protocol

Each Client is connected to each Server
Arrows indicate direction of data queries



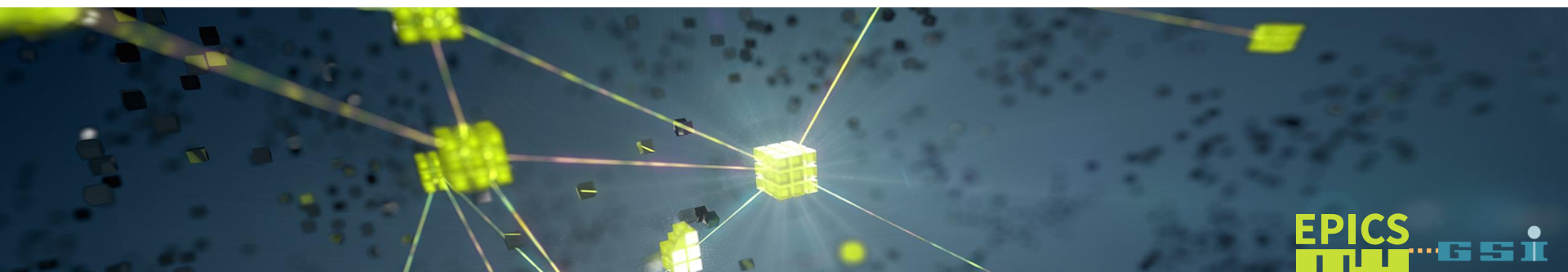
EPICS Communication Protocol

Using gateways to separate subdetectors from global DCS
Uni-directional connection!



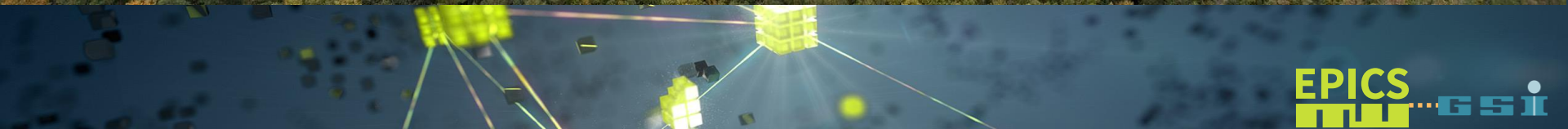
CBM

Compressed Baryonic Matter

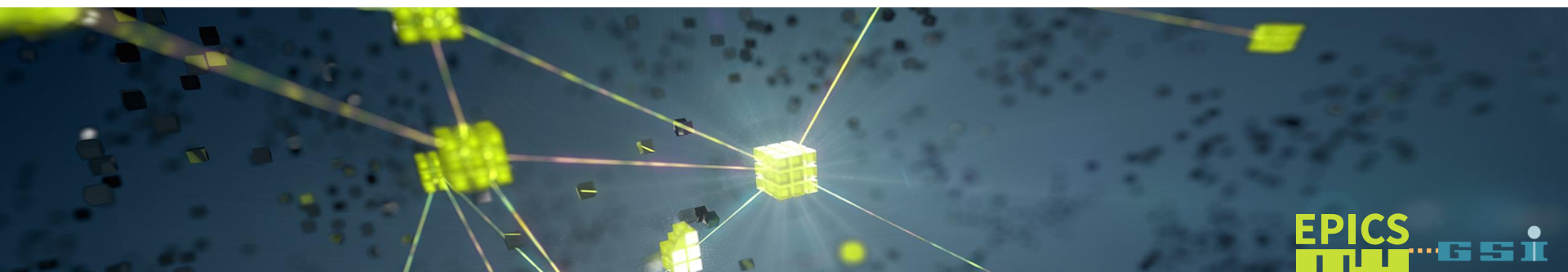




D.Fehrenz GSI/FAIR



Next talk by Marcel Bajdel



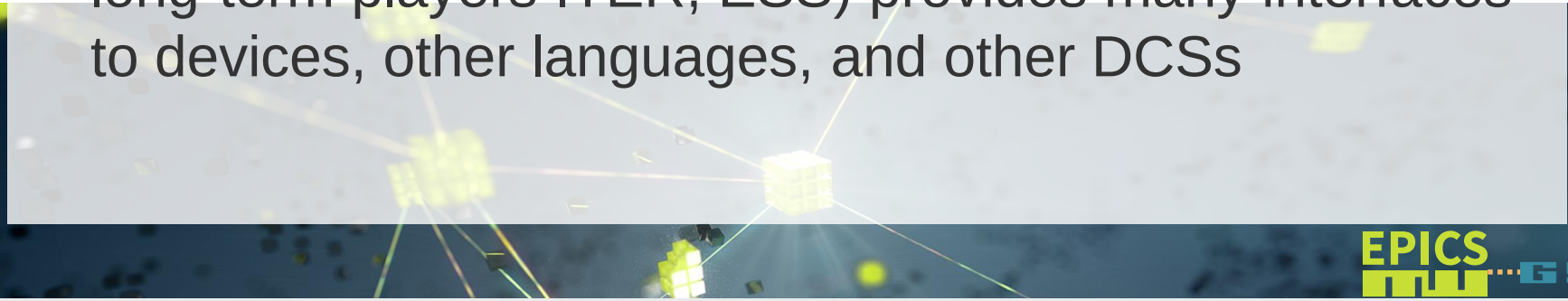
... no details

- further known EPICS setups at APPA
 - ask e.g. Raul Cantemir, thesis from GSI
 - gamma-ray setups, HV control



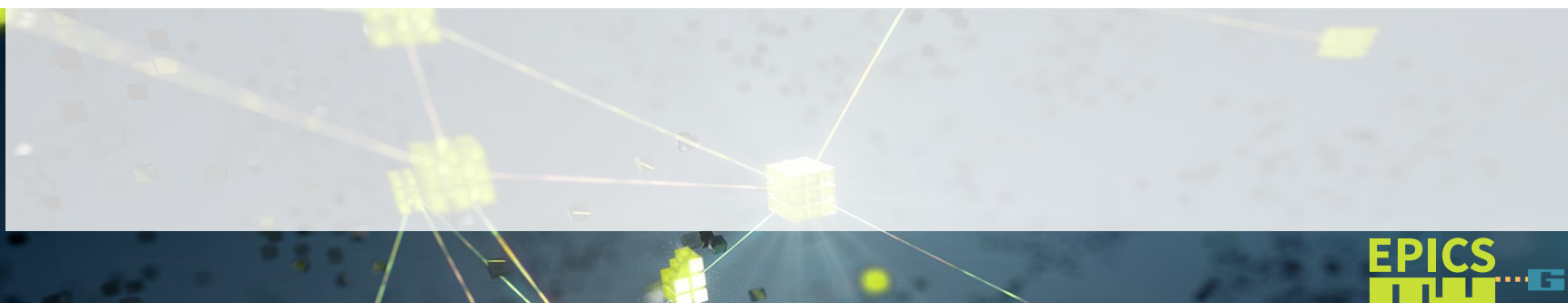
Summary

- What is EPICS
- several large scale, and scalable experiments use EPICS as their DCS
 - partly also as ECS (experiment control system) including data acquisition
- Due to its distributed ansatz it is well scalable
 - From small size table top to many 100,000 PVs
- EPICS' large community (>100 institutes worldwide, big long-term players ITER, ESS) provides many interfaces to devices, other languages, and other DCSs



more about EPICS

- <https://epics-controls.org>
- currently in parallel EPICS Spring Meeting
 - <https://indico.fnal.gov/event/58280/>
 - being recorded and after ~1 week available via the website
- mailing list „tech-talk“



THANK YOU

and:

F.Feldbauer

B.Loehner

M.Bajdel

HADES, CBM, R3B, PANDA

